**Trip F-1**

# A PRIMER ON UAV'S FOR GEOLOGICAL RESEARCH: EROSION AT MCINTYRE'S BLUFF, STERLING, NEW YORK


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## INTRODUCTION

The terrain of New York state from Rochester to Syracuse is covered with tens of thousands of drumlins, which formed during the last Ice Age (Figure 1). Drumlins are composed of largely unconsolidated Pleistocene glacial till. Intense erosive forces along the southeastern shoreline of Lake Ontario have progressively exposed the interiors of many of the drumlins which intersect the shoreline (Figure 1, red circle). McIntyre's Bluff, at Sterling Nature Center, is one of the more well-exposed shoreline drumlins (Figure 2). Others include Chimney Bluffs and Sitts Bluffs. These bluffs are separated by bays (such as Sodus Bay), ponds, or wetlands (Christensen et al., 1990; McClennen and Pinet,1990).

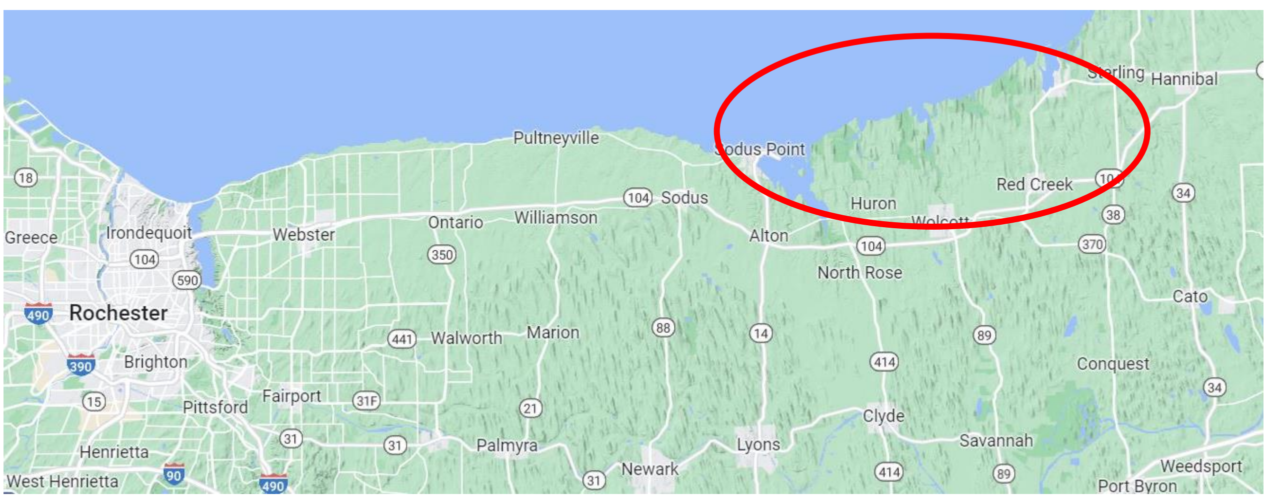


***Figure 1.*** *Thousands of drumlins cover the terrain between Rochester and Syracuse. These drumlins formed at the end of the last Ice Age, as the ice receded north. In the area of Sterling and Sodus Point (red circle) several very large drumlins intersect the lakeshore, and have been significantly eroded by the lake. McIntyre's Bluff, near Sterling, is one of these drumlins.*

Although the bluffs add to the majesty of the Great Lakes region, the intense erosive forces they are susceptible to cause them to degrade rapidly, and significant change can occur even within a single week. This degradation is particularly exacerbated during the winters, when intense freeze-thaw cycles along the cliff face accelerate erosion. Additionally, recurrent high lake levels throughout the year expose the cliffs to considerable wave action which contributes to the erosion process. Unexpected mass failures of these cliffs can cause weeks to months of inaccessibility until nature center trails are cleared and are deemed safe for pedestrian traffic, and can also irrevocably damage sensitive habitats.

The prevalence of coastal erosion by mass wasting and wave activity in this region have been well-documented by Brennan and Calkin (1984), Pinet et al. (1992), and Pinet et al. (1997). Also, surveys conducted by Drexhage and Calkin (1981) found that the erosion and retreat of shoreline bluffs can be attributed to factors such as bluff height and steepness (the steeper the slope, the faster the erosion); bluff orientation (bluffs that face NW appear to erode significantly faster due to the prominence of northwesterly winds in the region); bluff composition (mud-rich till erodes more rapidly); beach width (wide beaches help decrease erosion rate); beach composition (cobble style beaches tend to cause bluffs to retreat more rapidly, due to the promotion of high wave energy); and lake level (undercutting is more severe with higher lake levels and more energetic wave action).


***Figure 2.*** *McIntyres Bluff (red arrow) directly intersects the Lake Ontario shoreline. Erosion has exposed the interior of the drumlin, creating tall bluffs along the shoreline. These bluffs are composed of unconsolidated glacial till, which experiences intense erosion on a daily basis. Sitts bluff (west of McIntyre's Bluff) and Chimney Bluffs (off-map) have undergone similar erosional processes.*

The bluffs are also susceptible to biological erosion. For example, roots from vegetation progress extensively into the bluffs, and several species of birds are known to burrow into and nest within the soft bluff sediment (Figure 3a). Due to these erosive forces, it is not uncommon for the bluffs to undergo partial or total collapse and re-facing up to several times a year, especially following a rise in lake level or during and after rainy, icy or snowy conditions. Bluff faces also experience intense undercutting at times, when wave action on the lake is particularly energetic. In this case, the base of the bluff is more rapidly eroded than the top, leaving the top of the bluff unsupported from underneath, and susceptible to collapse (Figure 3B).

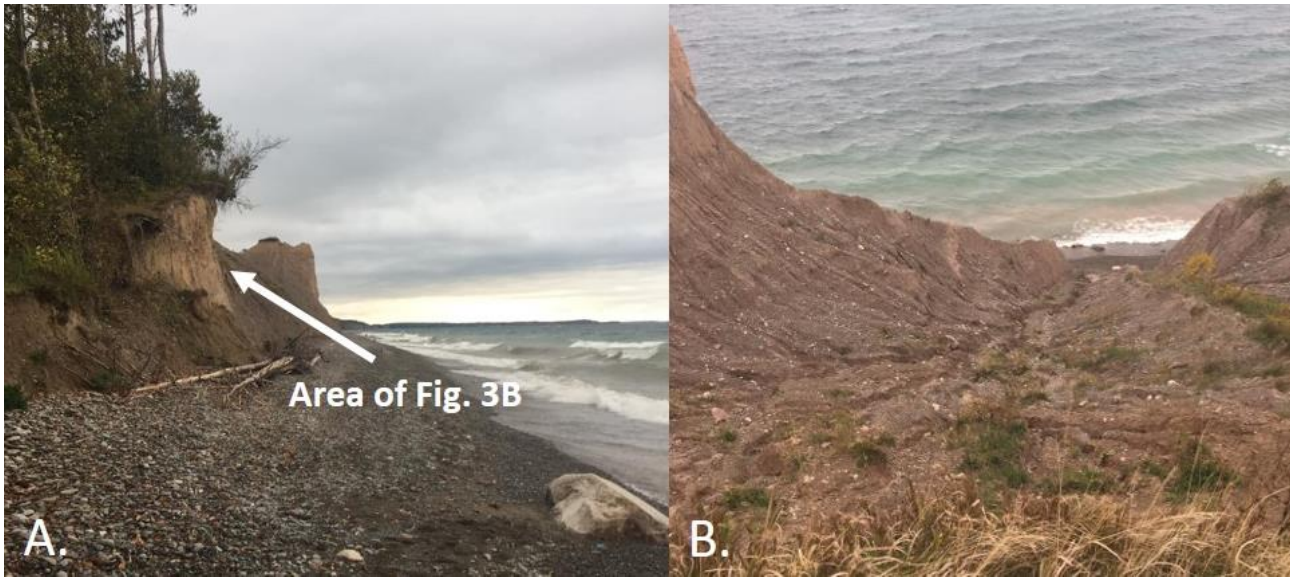


***Figure 3.* *A)*** *The shoreline at McIntyre's Bluff, early mid-2021. Unconsolidated sediments which make up the bluff continually erode to the beach, and the vegetated top of the bluffs experiences periodic slides and collapses.* ***B)*** *View from the top of the bluff, looking approximately 60 feet down towards the lake. The yellow arrow indicates the location of this view. Small gullies and rivulets formed by rain, snow, and ice can be seen on the drumlin surface.*

The average erosion rate of the bluffs is roughly estimated at 1 meter per year (Pinet et al., 1997); however, this rate was far exceeded during the winter of 2018 to the present. This is partially due to an increase in occurrence and intensity of spring and fall rainfall and several larger-scale lake effect snow storms, coupled with periods of higher lake levels from the implementation of Plan 2014, which aims to restore coastal wetlands through more natural regulation of lake water levels. Collectively, this has resulted in the rapid reorganization of loose glacial sediments that mantle the shoreline, and associated collapse of portions of bluff faces onto the shoreline and beach. The bluffs are progressively receding landward as they erode, making the top surfaces of the bluffs highly susceptible to degradation. Situated at the tops of many bluffs are residences and other infrastructure, which could be threatened by the progressive erosion. Public recreational activities along the shoreline are also significantly impacted. In May of 2018, extensive erosion at Chimney Bluffs State Park forced the main access trail to the bluffs and beach to close, as it became unsafe to traverse. Intermittent closings of the trail and beach have also occurred at McIntyre's Bluff. There are no signs of the erosion rate abating along the shoreline; rather it is becoming continually more pronounced.

Over the last several years, UAV imagery has been used in conjunction with 3D modeling with Agisoft Metashape, in an effort to quantitatively characterize the erosion rate at McIntyre's Bluff (Figure 4, 5). Collected imagery has, thus far, offered critical insight into how various environmental factors, particularly those related to progressive climate change - high lake levels, mild (or harsh) winters, excessive precipitation, etc. - impact the integrity of the bluffs on a regular basis.


***Figure 4: A)*** *Flying the Mavic UAV along the shoreline, collecting imagery of the bluffs* ***B)*** *An example of a 3D model of McIntyre's Bluff created using UAV imagery. The prominent cliff seen in A can also be seen in B. The 3D model was created using Agisoft Metashape software. Models such as this one can be directly compared with others from other time periods, and a percent change in the surface can be estimated.*

## FIELD GUIDE

The meeting point is Sterling Nature Center, Sterling NY. From the parking lot of the nature center, take the Shoreline Trail (trail #3). This trail goes down to the lakeshore. Turn left after reaching the lakeshore, and continue along trail #3 (along the beach) until reaching the base of McIntyre's Bluff.

**Stop #1**: This is the northeastern end of McIntyre's bluff (Figure 6). The bluff is significantly shorter in this area, and severe undercutting of the bluff by Lake Ontario can be seen. Biological erosion, via species of swallows which live in the bluff, is also apparent. This stop is arguably the best place to view the ever-changing surface of the bluff. Note the unconsolidated nature of the glacial till, and the significant difference in size and composition of the sediments. We will also examine the cobblestone beach in front of the bluffs.

**Stop #2:** These much taller cliffs represent the highest elevation area of the drumlin (Figure 6). Trail #11 goes along the top of the bluff at this location, which can be seen in the photo in figure 3B. The top of this cliff experiences regular mass movements, especially in the winter and spring months, as freeze/thaw processes occur. Walking up into the cliffside, note the significant gullies and rivulets which have been carved out of the cliffside by rain, snow, and groundwater activity. Groundwater periodically outlets from the cliff face here as small springs. The height of the cliffs in this area (60+ feet) make it ideal for UAV imaging, as inaccessible areas can be quickly and easily imaged.

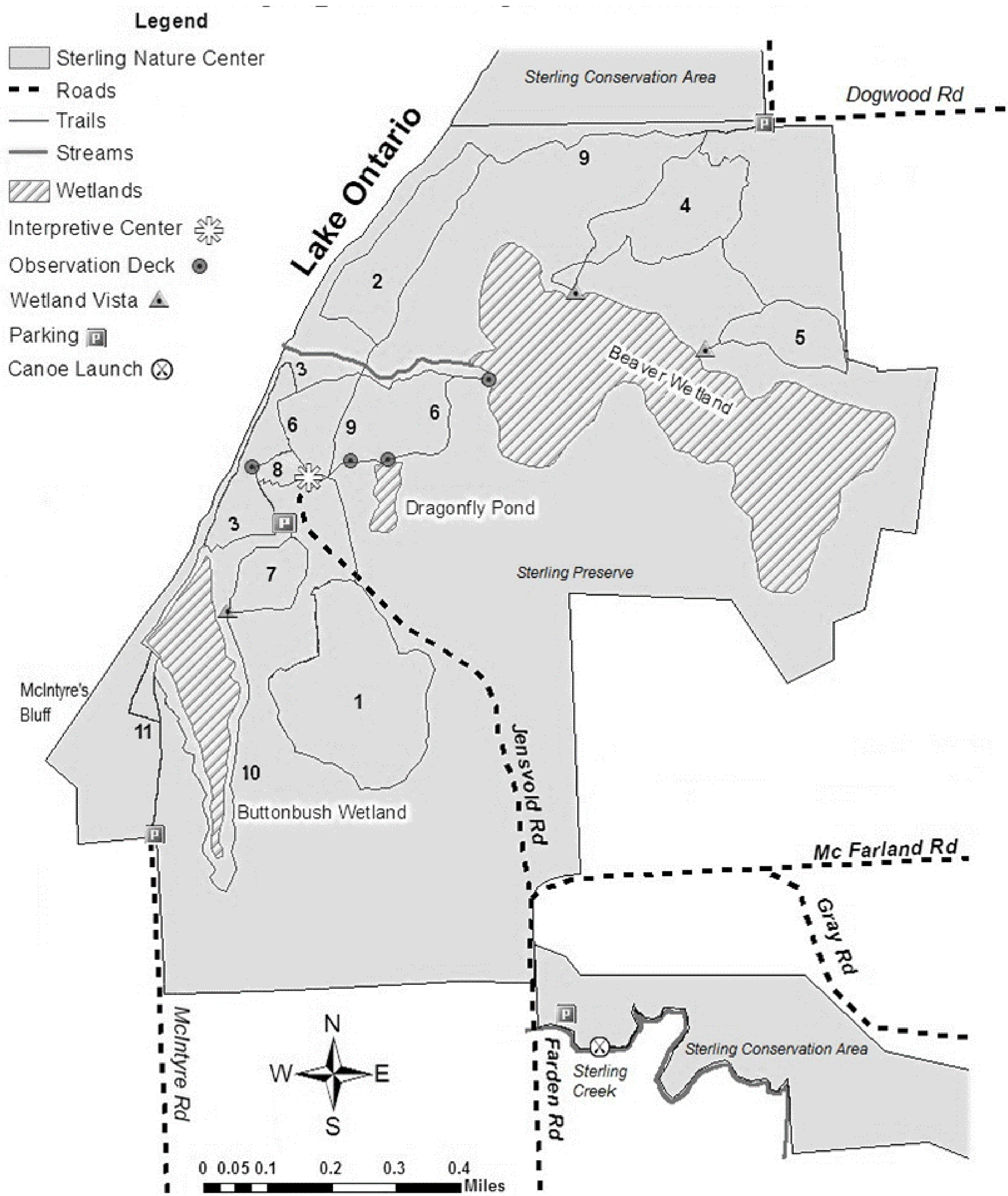


*__Figure 5__. Map of Sterling Nature Center, Cayuga County, New York*


***Figure 6.*** *Satellite view of McIntyre's Bluff. Note the intense erosion along the shoreline, which has extended back into the shoreline and up towards the top of the drumlin. Stop #1 and Stop #2 are denoted with red dots.*

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